III. *Experiments on the depolarisation of light as exhibited by various mineral, animal, and vegetable bodies, with a reference of the phenomena to the general principles of polarisation. By* David Brewster, *LL. D. F. R. S. Edin. and F. S. A. Edin. In a letter addressed to the Right Hon. Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read December 15, 1814.

Dear Sir,

Towards the end of the year 1812, when I was engaged in examining the light transmitted through diaphanous bodies, I discovered the property which many of them possessed of *depolarising* the rays of light, or of depriving them of the polarity which they had received, either by reflection from the surface of a transparent body, or by transmission through a plate of agate. A short account of these experiments, which were exhibited to many of my friends in Edinburgh, was soon afterwards published in my treatise on new philosophical instruments.

As this singular property was possessed by numerous substances that exhibited no marks of double refraction, and even by animal and vegetable products, such as horn, tortoise-shell, and gum Arabic, it appeared necessary to distinguish it by a new name, and to refer it to a species of crystallization different from that of doubly refracting crystals. The circumstance, however, of agate and Iceland spar possessing

the faculty both of polarising and depolarising light, and the constant relation in the position of the axes which regulated these apparently opposite actions, induced me to think that the two classes of phenomena had the same origin. This opinion was afterwards strengthened by an experiment with a bundle of glass plates, in which light was depolarised by polarising it in a new plane; but in applying the principle to other phenomena, I was baffled in every attempt to generalise them. By extending, however, and varying the experiments; by examining the optical properties of every substance which I could command, and by comparing their structure with the phenomena which they exhibited, I have been led to the general principle to which they all belong, and to a series of results which, from their very nature, could not easily have been established by direct experiment. These conclusions, independently of their optical consequences, are peculiarly interesting to the chemist and the natural philosopher, by disclosing the structure of organised substances, and exhibiting new relations among the bodies of the animal, the vegetable, and the mineral kingdoms.

In proceeding to illustrate this subject, I shall first give some account of the experiments on which the theory is founded, and then explain the theory itself, and the conclusions which it seems to involve.

I. *Experiments on the depolarisation of light.*

I have already explained, in a former paper,* the general phenomena of depolarisation, and have shewn that almost all regularly crystallized bodies, such as plates of mica, of calca-

* Philosophical Transactions, 1814, Part I, p. 199.

reous spar, and of topaz, have two *neutral* axes at right angles to each other, and two *depolarising* axes at right angles to each other, and forming angles of 45° with the neutral axes.

In *mica,* the neutral axes coincide with the diagonals of its primitive rhomboidal base.

In *calcareous spar* the neutral axes are coincident with the diagonals of any of its rhomboidal faces, while the depolarising axes are parallel to the sides of these faces; but when polarised light is transmitted along the short diagonal of the rhomb itself, there is no position in which it is depolarised, or in which the two images continue visible during the whole revolution of the prism of calcareous spar next the eye. The evanescent image is no doubt restored by the interposition of the rhomb, but this only shifts the vanishing place of the images which will continue to disappear alternately in every quadrant.

In *topaz,* the neutral axes coincide with the diagonals of the base of its primitive right prism, and the depolarising axes are parallel to the sides of any of its square faces.

The minerals, in which I have not found the property of depolarising light, are *muriate of soda,* or rock salt, *fluor spar,* and a crystal of *spinelle ruby.* I have cut numerous plates in different directions from a cube of muriate of soda, and have tried many specimens of fluor spar, but in none of them could I discover the least trace of depolarising axes.

The only mineral which depolarises light in every position, and therefore possesses no neutral axes, is the *diamond.* Out of *fourteen* specimens of this gem which I examined, *seven* depolarised light in every position; *four* did not depolarise light at all; *one* depolarised about a fifth part of the light,

one about half of the light, and *one* nearly the whole of the light.

Semi-opal, like the diamond, depolarises light in every position; but there is an obvious approximation to neutral axes.

In employing another class of bodies, we are presented with a series of very singular results, which not only develope new affections of light, but lead to important conclusions respecting the crystallization of organised and unorganised bodies.

1. *Gum Arabic.* This vegetable substance, which is formed by concentric coats, has no neutral axes; but depolarises light in every position. In a very thin chip, however, the neutral axes are distinctly visible. With a strong solution of gum Arabic in water, I formed a thin film of it upon a plate of glass. In two or three days it became very hard, but though I have kept it six months, it has not acquired the property of depolarising light.

2. *Gum from the cherry tree.* A plate of this gum about one-twentieth of an inch thick, and so soft as to yield to the gentlest pressure of the nail, depolarises light, but the image does not wholly vanish in the neutral axes. Another plate of the gum, but exuded from a different part of the same tree, and much softer than the former, depolarises only a small portion of light.

3. *Caoutchouc.* This gum is composed of concentric or parallel layers of a vegetable juice, which are successively indurated by exposure to the sun. When a thin plate of it is made transparent by pressure between two plates of glass, it exhibits no neutral axes, but depolarises light in every position, in whatever direction the film is cut from the mass.

When the film was so extremely thin, that it could not be made transparent by pressure between two plates of glass, I stretched it over the mouth of a tube upon a piece of plane glass, and prevented it by means of a cord from recovering its shape. A layer of Canada balsam being then placed both below and above the caoutchouc, and another plate of glass laid upon the upper layer of balsam, the film became perfectly transparent. When exposed to polarised light, it exhibited *neutral axes*, like the most perfect crystals.

When caoutchouc is dissolved by heat, it loses completely its property of depolarisation, but it gradually recovers its former structure, and after a certain number of days, it is again capable of depolarising light. A piece of caoutchouc, which had been melted by heat, resumed its faculty of depolarisation at the end of twenty-five days; but upon pressing it gently with my finger, its structure was again destroyed, and at the end of nineteen days, it depolarised a small portion of nebulous light. Another piece of caoutchouc, dissolved by heat, had not recovered its crystalline state at the end of six days. After standing eighteen days, it depolarised a considerable quantity of light, and at the end of five or six weeks, it was capable of restoring the whole of the vanished image.

4. *White wax.* When a piece of wax is melted and cooled between two plates of glass, or when it is merely pressed between them by the heat of the hand, it depolarises light in every position. The restored image, however, has a nebulous appearance.

5. *Rosin and white wax mixed.* Rosin alone has not the property of depolarising light. When it is mixed with an equal part of white wax, and is pressed between two plates of glass

by the heat of the hand, the film is almost perfectly transparent by transmitted light, though of a milky white appearance by reflected light. It has not the property of depolarisation when the *polarised pencil is incident vertically*, but it possesses it in a very perfect manner at *an oblique incidence*, and exhibits the segments of coloured rings.

6. *Cells of the bee.* The waxen partitions of the honey-comb, when rendered transparent by layers of Canada balsam, depolarise light in every position.

7. *Manna.* This substance, when melted by heat between plates of glass, depolarises light in every position.

8. *Camphor.* A small piece of this substance when pressed between two plates of glass, without the application of heat, depolarises light in every position.

9. *Balsam of Tolu.* When a thin plate of this substance is formed between plates of glass with the assistance of a gentle heat, it depolarises light in every position; and a considerable degree of heat is necessary to deprive it of its crystalline structure. When it is allowed to cool very slowly, it does not acquire the property of depolarisation.

10. *Withered film at the root of the Calla Ethiopica.* This vegetable film depolarises light, and possesses distinct neutral axes which are parallel and perpendicular to the stalk of the plant, or to the parallel veins in the film.

11. *The fibres of flax, hemp, and cotton.* These vegetable fibres depolarise light, and have perfect neutral axes parallel and perpendicular to the axes of the fibres.

12. *The thin white semi-transparent leaf of the sea-weed* depolarises a small portion of light, and its neutral axes are parallel and perpendicular to the axis of the leaf.

13. *Adipocire from muscular fibre.* This substance melts as easily as white wax. It depolarises light in every position, and crystallizes differently from wax, manna, and spermaceti.

14. *Adipocire from the burying ground of the church des Innocens at Paris.* This substance melts at as low a temperature as the preceding, and when cooled between two plates of glass, it crystallizes in concentric rings which appear through the microscope like clusters of islands in a map, surrounded with engraved circles. It has no neutral axes, but depolarises light in every position.

15. *Adipocire from biliary calculi.* This body crystallizes exactly like benzoic acid, which it resembles in appearance, shooting out spicula at angles of about 20°. It requires a very considerable heat to melt it; crystallizes rapidly, and depolarises light in every position.

16. *The benzoic and oxalic acids,* when melted by heat, and then cooled, depolarise light in every position.

17. *Spermaceti.* This substance, when melted and cooled, depolarises light in every direction; and when pressed between two plates of glass without the aid of heat, it exhibits traces of coloured rings by polarised light.

18. *Gold beaters' skin.* Having procured a remarkably thin film of this animal substance, I rendered it transparent by placing it between layers of Canada balsam. It possessed the property of depolarising light, but it did not restore the whole of the evanescent pencil. Its neutral axes were not so perfectly developed as in the thin film of caoutchouc.

19. *Transparent and common soap.* A plate of transparent soap of any thickness depolarises light in every position; and

a thin film of the common yellow and white soap has the same property.

20. *Human hair.* The fine transparent hair of a child depolarises light, and possesses the most perfect neutral axes. These axes are parallel and perpendicular to the axis of the hair.

21. *Bristles of a sow* possess the same properties as hair. The neutral axes are seen more distinctly in this than in the preceding experiment, on account of the greater magnitude of the bristles.

22. *The fibres of silk and wool* depolarise light, and have neutral axes parallel and perpendicular to the axes of the fibres.

23. *The silkworm gut* and *sheep gut* depolarise light. In the former the neutral axes are perfectly developed, but in the latter there is merely an approximation to them.

24. *The human cuticle* depolarises light in every position.

25. *Parchment* depolarises light in every direction. In two positions, at right angles to each other, the restored image is indistinct and principally nebulous; while in other two positions at right angles to each other, at angles of 45° with the former, the restored image is distinct.

26. *The horny excrescence* on the human foot depolarises light in every position.

27. *The transparent film* at the joints of the claws of the common Partan depolarises light; and has neutral axes parallel and perpendicular to the length of the claw.

28. *The human nail* depolarises light in every position.

29. *A quill*, and the *thin film* which lines the inside of it, depolarise light. The former exhibits coloured rings, and the latter has distinct neutral axes.

30. *The cartilaginous breast bone of a chicken* depolarises light, and has neutral axes parallel and perpendicular to the longitudinal direction of the bone.

31. *The transparent cartilage* from the shoulder of a sheep has neutral axes, and produces the coloured rings by polarised light.

32. *The transparent edge* of the small fibres which compose the feathery part of a *quill* depolarise light, and have their neutral axes parallel and perpendicular to the axis of the fibre. It forms also an extraordinary prismatic image of the candle by transmitted light.

33. *The down of goose and ostrich feathers* depolarise light. Feathers from the neck and tail of a cock have neutral axes parallel and perpendicular to the direction of the fibres.

34. *Flat bones of a cod.* These bones depolarise light in every position, and exhibit coloured rings by polarised light. The soft cartilaginous substance, which is sometimes connected with them, possesses the same properties.

35. *Cylindrical bones of fish.* These bones depolarise light, and have their neutral axes parallel and perpendicular to the axis of the cylinder. They exhibit also colours by polarised light.

36. *Ivory.* A very thin film of ivory possesses neutral and depolarising axes, as perfectly as the most regularly crystallized mineral. When the vanished image is restored by the ivory, the intensity of the light of the other image is very much diminished, the difference between the two images being greater than I have found it in any other body. The film of ivory forms by transmitted light two highly coloured images

on each side of the common image, like those which I have described in my paper on mother of pearl.*

37. *Whalebone* depolarises light, and has neutral axes parallel and perpendicular to the direction of the fibres.

38. *Horn.* This substance also depolarises light in every position, and exhibits the coloured rings by polarised light.

39. *Mother of pearl* depolarises light in every position when the polarised pencil has a small angle of incidence; but when the angle of incidence is about 60°, and the plate about the thirtieth of an inch thick, it acts exactly like a bundle of glass plates, shifting merely the vanishing place of the image. †

40. *Bladder of a cow* depolarises light in every position.

41. *Human cornea* depolarises light in every position, and exhibits coloured rings by polarised light. The *tunica retina* and the *crystalline lens* exercise no peculiar action on light.

42. *Cornea of a cow* depolarises light in every position, and exhibits colours by polarised light. When it is pressed hard between the lenses, so as to induce a milky opacity, it still retains the power of depolarisation. The crystalline lens does not possess any of these properties.

43. *Cornea of a fish* depolarises light in every position, but most powerfully near its junction with the sclerotic coat, and exhibits coloured rings by polarised light. The crystalline lens, the sclerotic coat, and the capsule of the crystalline lens, exercise no action upon polarised light. When two capsules

* Phil. Trans. 1814. Part II. p. 397.

† We have here omitted the consideration of the nebulous image formed by mother of pearl at an oblique incidence. An account of the remarkable optical properties of this substance has been given in another paper.

were put together, a partial depolarisation took place, arising probably from the obliquity of the folds.

44. *Glue* depolarises light in every position.

45. *Hard isinglass* depolarises light in every position. When dissolved in water, it acquires this property a few hours after coagulation.

46. *Acetate of lead.* This salt melts at a temperature not much greater than that of bees' wax, and takes a long time to cool and crystallize. It depolarises light in every position. When the plates of glass, in which it is included, are considerably inclined to each other, the acetate of lead developes a second image in the act of cooling, but owing to the crystallization which takes place, both the images are imperfectly visible. Its refractive power increases a little after crystallization, and the new image that is developed is the one that is most refracted.

47. *Glass of borax.* A thick piece of this glass depolarises light in every position. Another piece of considerable thickness had no effect upon polarised light.

48. *Amber* sometimes depolarises light in every position, and sometimes exhibits neutral axes.

49. *Gum anime.* A piece of this gum, three quarters of an inch thick, depolarises light in every position, and seems to produce the complementary colours by polarised light. Small fragments of it depolarise only a small quantity of light.

50. *Sulphur,* when melted between two plates of glass, depolarises light in every position. It acquires this property in a few minutes.

51. *Ice.* Some plates of ice depolarise light in every position, while others exhibit neutral axes.

52. *Oil of mace.* This soft solid exhibits optical properties of a very peculiar character. When it is pressed into a thin film between two plates of glass without the aid of heat, it depolarises light in every position. It melts nearly at the temperature of blood heat, and takes a long time to cool and crystallize. If a thin plate of it is melted, and afterwards cooled between two pieces of glass, the image of a candle when seen through some parts of it, is encircled with a halo of nebulous light, varying in different plates from 0° to 16° in diameter, and having its central parts of a bluish colour, and the circumference of a reddish brown hue. In other parts of the film the halo disappears.

When the polarised light of a candle is transmitted through those parts of the film which do not produce the halo, it is depolarised in every position; but when the light is transmitted through the marginal parts, or those which produce the halo, the oil of mace restores *four wings of light* or *four luminous sectors*, in the centre of which is the place of the evanescent image. Through intermediate parts of the film, it depolarises two luminous images of the candle, separated by a narrow dark space, and manifestly formed of condensed nebulous light. Upon moving the film from the position which gives the luminous sectors, into that which gives the complete image of the candle, the wings or sectors gradually diverge from their common centre, and then vanish; and upon moving the film from the same position into that which gives the two luminous images, each adjacent pair of the sectors approach one another, and are condensed into two luminous semi-circles, which form the two images already mentioned. In the dark space between these two images, the

vanished image reappears by the slightest motion of the prism of calcareous spar. In some plates of oil of mace, this dark interval is occupied with a third image, so that the depolarised image has the appearance of being composed of *three images* closely pressing upon each other. In other plates the bright image is partly depolarised, even when the luminous sectors are visible.

The phenomena of the luminous sectors will be understood from Pl. V. fig. 1, where AB is the plane in which the light of the candle is polarised, and MN the two images of it formed by a prism of calcareous spar, *m* being the place of the vanished image, and *n* the visible image. The evanescent image at *m* is surrounded with the four luminous sectors 1, 3, 5, 7, separated by dark sectors 2, 4, 6, 8. The bright image of the candle at N is also surrounded with four luminous sectors 9, 11, 13, 15, separated by dark sectors 10, 12, 14, 16; but these sectors, of which 11 and 15 are the brightest, are not nearly so luminous as those at M.

If the oil of mace is kept in one position, while the prism of calcareous spar is turned round so as to make the image N move about M, as a centre in the direction BC, the evanescent image of the candle begins to appear at *m*: the luminous sectors turn round in the direction 1, 2, 3, 4, 5, 6, 7, 8: the sectors 1, 5 grow fainter, and 9, 15 brighter; and after the image N has moved through an arch of 45°, the two images M and N have nearly the same appearance. When the image N has described an arch of 90°, the sectors have the appearance represented in fig. 2, the candle having regained its full lustre in the middle of M, and having vanished in the middle of *n*. The sectors 1, 5 are now the faintest of those round

m, all of which are much inferior in brilliancy to those with which *n* is encircled.

When equal parts of *rosin* and *oil of mace* are mixed together, a film formed out of the mixture depolarises, imperfectly, the four luminous sectors.

53. *Tallow.* When tallow is melted between two plates of glass, and then slowly cooled, it exhibits no optical indications of a crystallized structure. After having stood five or six days, an incipient crystallization is exhibited in the property which it acquires of depolarising a small portion of nebulous light. This nebulosity gradually increases: about the eleventh day, it assumes an imperfect resemblance to the four luminous sectors produced by oil of mace; and about the sixteenth day, the form of the sectors is fully developed. Another plate formed of the fat of mutton, after standing five months, has acquired in some parts the property of depolarising a portion of nebulous light, while, in other parts, it depolarises a small part of the bright image. In a third plate, suddenly cooled by immersion in cold water, very faint traces of four large luminous sectors were visible by a careful exclusion of extraneous light.

54. *Tortoise shell* depolarises light in every position, and produces the coloured rings by polarised light. When a candle is viewed through tortoise shell, it is surrounded with a double halo, which becomes elliptical by inclining the plate to the incident rays. When the polarised light of a candle is depolarised, the restored image is surrounded with four very faint luminous sectors, like those in oil of mace.

55. *Heated glass.* When glass is brought nearly to a red heat, it depolarises light in every position, and the quantity

of depolarised light diminishes gradually with the temperature.

56. RUPERT's *drops of unannealed glass.* When drops of melted glass are suddenly cooled by immersion in cold water, they acquire the faculty of depolarising light in every position, and of exhibiting the coloured rings by polarised light. At a certain thickness of the tail of the drop, the neutral axes are perfectly developed, and are parallel and perpendicular to the axis of the tail.*

57. *The semi-transparent and flat extremity of one of the legs of a young partan* gives only a nebulous image of a candle, but depolarises the nebulous light in every position.

58. A *tubular film* from the body of a partan, depolarises a small quantity of nebulous light.

The following table contains a list of substances chiefly of animal and vegetable origin, which have no effect in depolarising light.

Gold leaf.	Sclerotic coat of a fish.
Some crystals of diamond.	Crystalline lens of a fish.
Muriate of soda.	Crystalline lens of a cow.
Fluor spar.	Capsule of the crystalline lens of a fish.
A crystal of spinelle ruby.	Ambergris melted and cooled.
Muriate of ammonia.	Film which surrounds the hydatids.
Rochelle salts dissolved, and crystallized on the side of a glass.	Delicate film which lines the ribs of a lamb.
Nitrate of lead dissolved, and crystallized on the side of a glass.	Film from the stalk of the rhubarb.
	Film, or epidermis, which covers the shell *solen ensis*.

* A full account of the properties of heated and unannealed glass will be found in two former papers. (Phil. Trans. MDCCCXIV. Part II. p. 436, and MDCCCXV. Part I. p. 1.)

Resin of bile melted and cooled.
Jelly from calves' feet.
The skin of a fowl.
Scale from the body of a bee.
Hair of a bee.
Wing of a bee.
Wing of a house beetle.
Wing of the May fly.
Wing of the stone fly.
The byssus, or hair from the *pinna marina.*
Wing of the *meloë vesicatorius.*
Film which covers the tubular stalk of the *leontodon taraxacum.*
Film between the coats of an onion.
Film on the leaf of the American house leek.
Leaf of the hydrangea.
Spatha of a lily.
Film of gum Arabic formed by evaporation.
Rosin.
Gum copal.
Thin fragments of gum anime.
Gum galbanum.
Gum juniper.
Canada balsam indurated.
The spheres on sea-weed.
Film which lines the stalk of the *fleur de lys.*
Thin slices from a wafer.
Filaments of the pappus of the *leontodon taraxacum.*
Film which lines the shell of an egg.
Skin of a dried grape.
Phosphorus.
Hair from the fur of a seal.
Skin of an infant eleven months old.
Skin of a child two months before birth.
Skin of a herring.
Gum mastic.
Burgundy pitch.

II. *Theory of the depolarisation of light.*

The various modes in which bodies depolarise light may be reduced to *seven.*

1. When the crystal possesses neutral axes, and forms two images which are capable of being rendered visible, as in *calcareous spar, topaz,* &c.

2. When the crystal possesses neutral axes and exhibits only a single image, as the *human hair* and various *transparent films.*

3. When the crystal has no neutral axes, but depolarises light in every position, as in *gum Arabic, caoutchouc, tortoise shell,* &c.

4. When there is an approach to a neutral axis, as in *gold-beater's skin*, &c.

5. When the crystal depolarises, or restores only a part of the polarised image, as in a *film of sea-weed* and a *film* from the *partan*.

6. When the crystal depolarises luminous sectors of nebulous light, as the *oil of mace*.

7. When the crystal restores the vanished image, but allows it to vanish again during the revolution of the calcareous spar.

1. The *first* of these modes of depolarising light admits of an easy and satisfactory explanation.

Let R*r*, fig. 3, be the light of a candle completely polarised by reflection in the direction *r*S from the surface of the transparent body AB. If this light is viewed through a prism of calcareous spar CD,* when its principal section is neither coincident with, nor perpendicular to the plane of reflection R*r*S, two images of the candle will be seen; but upon turning round the prism CD, one of the two images will vanish alternately in every quadrant of the circular motion of the prism. Let the prism therefore be fixed in the position which it has when one of the images has vanished, in which case the principal section will be either parallel or perpendicular to the plane R*r*S. If a rhomb of calcareous spar MNOP is now interposed, so that the principal section MN is either parallel or perpendicular to the plane R*r*S, the vanished image will still be invisible. Upon turning round the rhomb MNOP, the

* Another prism is represented in the figure for the purpose of correcting, as much as possible, the refraction and dispersion of the prism of calcareous spar.

vanished image will begin to appear, and when MO is in the plane of reflection R*r*S, it will have reached its maximum brightness. It will again vanish when OP is in the *plane of* reflection, and will again recover its lustre when ON is in that plane, having vanished and reappeared *four* times in the course of one revolution of the rhomb. If the rhomb MNOP is kept fixed when the vanished image has reappeared; and if the prism CD is turned round, the two images will continue visible during every part of its circular motion, and hence the polarised ray *r*S, seems to have been robbed of its polarisation or depolarised.

In order to explain these appearances, let CD be fixed in its former position, and let the rhomb MNOP have its principal section or neutral axis in the plane R*r*S. This rhomb is known to give two images of the candle formed by rays ST, SV, nearly coincident, but owing to its present position, one of the pencils, that would have moved in the direction ST, refuses to penetrate the rhomb, and therefore only one pencil SV, polarised in the same manner as *r*S, falls upon the prism CD. Now this prism being obviously placed in the position where its power of doubling SV is extinguished, that is, where one of the pencils, into which it separates SV, has vanished, a single image E of the candle will still only be visible, notwithstanding the interposition of the rhomb. The very same reasoning is applicable to the case where the longer diagonal OP is in the plane of reflection.

The prism CD continuing fixed, as before, let the side MO, or the depolarising axis of the rhomb, be brought into the plane of reflection. In this situation of the crystals, both the pencils ST, SV, fall upon the prism CD, which has now the

particular position that enables it to double each of these pencils; so that *four* images of the candle 1, 2, 3, 4, will now be visible. As the rhomb MNOP produces only a very small separation of the pencils ST, SV, the two images 1, 2, will overlap each other, and resemble only one image at E, while the other two images 3, 4, will appear as a single image at F. Every thing remaining fixed, let the prism CD be turned round in a plane perpendicular to ST. The effect of this will be to extinguish one of each of the double images E and F at every quarter of a revolution, that is, first the images 1 and 3, then the images 2 and 4, then the images 1 and 3 again, and last of all the images 2 and 4. Still, however, one image is always left at E and another at F, so that when the polarised ray *r*S passes through the depolarising axis MO of the rhomb, the two images E and F continue visible in every part of the motion of the prism. The depolarisation, therefore, of the pencil *r*S, is nothing more than the polarisation of it in a new plane, and the depolarising rhomb MNOP acts in every respect like a doubly refracting and polarising crystal.

2. In the *second* kind of depolarisation where the *human hair*, or a *plate of mica* is substituted in place of the rhomb of calcareous spar, the phenomena are precisely the same as those which have been described in the preceding section, and therefore we are necessarily led to suppose that the human hair and the mica form two images polarised in an opposite manner, like those given by calcareous spar. These two images indeed being produced by the same, or nearly by the same refractive power, cannot be rendered visible by any contrivance; but when we consider that the depolarising axes of the mica coincide with the long and short diagonals of its

primitive rhomboidal base, as in the case of calcareous spar and topaz, and that there is a variation in the intensity of the light of the images E and F, during the revolution of the prism, we must consider the existence of two oppositely polarised images as no longer problematical.

Hence it follows, that every substance which possesses the property of depolarising light in the second manner, must necessarily form two coincident or nearly coincident images polarised in an opposite manner; or to speak more correctly, a pencil of common light transmitted through depolarising crystals, consists of a portion of light polarised like one of the pencils formed by calcareous spar, and of another equal portion polarised like the other pencil formed by calcareous spar.

Depolarising substances, consequently, are not entitled to the name of *doubly refracting crystals*, when the two oppositely polarised pencils are not capable of being separated from each other, and till this separation is actually *seen*, we must consider the two pencils as produced by the same refractive power.

We would therefore propose to designate all substances that form two separable images, such as calcareous spar, quartz, topaz, &c. by the name of *doubly refracting crystals*, and those which do not form two separable images, such as diamond, mica, heated glass, the human hair, &c. by the name of *doubly polarising crystals*.

3. The *third species* of depolarisation is characterised by the substance having no neutral axes, and depolarising light in every position; and is possessed by *gum Arabic*, *caoutchouc*, and many other bodies which are known to be formed by the successive deposition and induration of thin layers.

When the first layer of gum Arabic or caoutchouc is deposited and crystallized, it will possess both neutral and depolarising axes like every other crystal. The second layer will likewise have these axes, but there is manifestly no cause which can make the neutral and depolarising axes of the second layer coincide with those of the first layer; so that after a number of layers are formed, there will be a depolarising axis in every direction. In order to illustrate this conclusion by direct experiment, we have only to place one plate of mica above another, so as to make the neutral axis of the one coincide with the depolarising axis of the other. It will then be seen that all the axes become depolarising axes, and that the compound crystal acts upon light exactly like gum Arabic and caoutchouc. If this explanation be correct, we should expect to find, that a film of gum Arabic or caoutchouc, reduced to a less thickness than any individual layer, would exhibit its neutral axes, and lose the property of depolarising light in every position. This interesting result I have repeatedly obtained both with gum Arabic and caoutchouc, as described in experiments 1 and 3, so that we have both a synthetical and an analytical proof of the explanation which has been given of the *third* kind of depolarisation.

Hence it follows, that all substances which depolarise light in every position, are formed by layers successively deposited and crystallized; that every layer has neutral and depolarising axes, like regularly crystallized bodies; and that the axes of one layer is not related in point of direction to those of its adjacent layers.

4. The *fourth* kind of depolarisation is exhibited in the film of gold beaters' skin, where there is an approach to a neutral axis.

When a body is composed of two or more films whose neutral axes are nearly coincident, the compound film will exhibit the fourth kind of depolarisation, and the approximation to a neutral axis will be more or less perfect, as the coincidence of the axes is more or less complete. This phenomenon is most likely to be exhibited by thin plates which are composed of a small number of films.

Hence every body, in which there is an approach to a neutral axis, must be composed of two or more films, whose neutral axes happen to be nearly coincident. These films are probably deposited and crystallized at different times; or if their crystallization has been simultaneous, the forces, or causes by which it was produced, must have acted independently of each other.

5. The *fifth* kind of depolarisation takes place when there is an approach to a depolarising axis, or when the crystal restores only a portion of the vanished image.

If we suppose one part of a body to have no crystalline texture, while another part of it has the structure necessary to depolarise light, it will exhibit correctly the *fifth* kind of depolarisation. The uncrystallized portion being incapable of restoring any part of the vanished image, the light which it transmits will form no part of the depolarised pencil, which will consist merely of the rays transmitted through the structure which has the property of *double polarisation.* The magnitude, therefore, of the depolarised pencil will be a measure of the portion of the substance which has undergone crystallization. From the phenomena of caoutchouc, this explanation derives great support. When the crystalline texture of this substance has been destroyed by heat, it ceases to act upon

polarised light. After it begins to crytallize, however, a *small portion* of light is at first depolarised. This portion gradually increases, and the image is not completely restored till the crystallization has pervaded the whole mass. The experiments with oil of mace furnish us with another proof of this explanation, and exhibit a case in which a part of the substance is permanently crystallized, while another part of it is permanently uncrystallized.

Hence we may conclude, *that bodies which depolarise only a portion of light, either consist of permanently crystallized and uncrystallized portions, or are in a state of approach to a perfect crystalline structure, the crystallized portion being always proportional to the quantity of depolarised light.*

6. The *sixth* kind of depolarisation is exhibited in the curious phenomena of *oil of mace,* which sometimes depolarises *four* sectors of nebulous light.

Those plates of oil of mace, in which the luminous sectors are alone depolarised, have obviously two structures, namely, that which forms the bright, and that which forms the nebulous image. The structure which forms the bright image has no more action upon light than a mass of water, as it does not in the slightest degree alter its polarity; but the structure which forms the luminous halo possesses a peculiar character. If we suppose the halo to be divided, as in Pl. V, fig. 1; into eight sectors 1, 2, 3, 4, 5, 6, 7, 8, every alternate sector 1, 3, 5, 7, is polarised in the same manner as the incident light, while the other sectors 2, 4, 6, 8, are polarised in an opposite manner. Now, if this halo consisted only of one nebulous image, the evanescence of every alternate sector would take place without applying the calcareous spar, and merely by

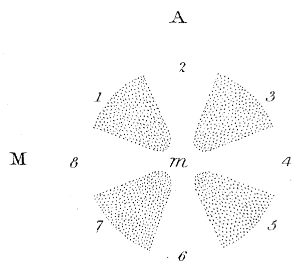
transmitting polarised light through the oil of mace; but as this is not the case,* it necessarily follows that there are *two* halos, or nebulous images, the one lying exactly above the other, and having every alternate sector polarised in an opposite manner, while each sector in the one image has an opposite polarisation to the corresponding sector in the other image. An idea of this curious property may be formed from fig. 4, in which we have shown the two halos at a distance, and distinguished the opposite kinds of polarisation by the signs + and −.

Those parts of oil of mace which depolarise a portion of the bright image, while they form the luminous sectors, have therefore the faculty of forming *four images*, two bright and two nebulous, possessing the characters which have already been described.

The two adjacent images which are formed by some portions of the plate of oil of mace, are obviously produced by the sectors 1, 7, and 2, 5, fig. 1 being condensed on each side of *m*, and when three images are depolarised, the third image is a portion of the bright image restored at *m*, the place of its evanescence.

If we knew in what way the halo itself is formed, there would probably be no difficulty in explaining these remarkable phenomena. The diameter of the halo is too small to allow us to suppose that the polarisation of the sectors can be effected by oblique reflection or refraction, and though it is extremely probable that light is partially polarised by inflexion

* In some instances, when we examine the halo formed by polarised light without applying the calcareous spar, the two sectors in the plane of polarisation are less luminous than the rest.



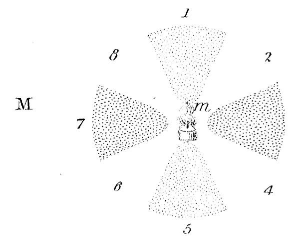
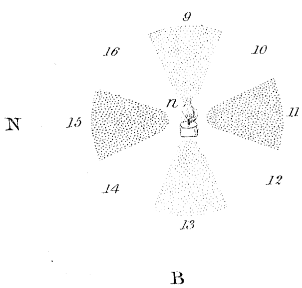


Fig. 1.

Luminous Sectors exhibited by Oil of Mace.

Fig. 2.



C

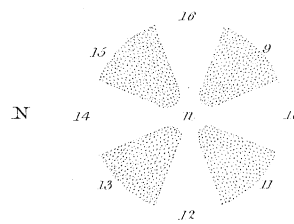


Fig. 3.

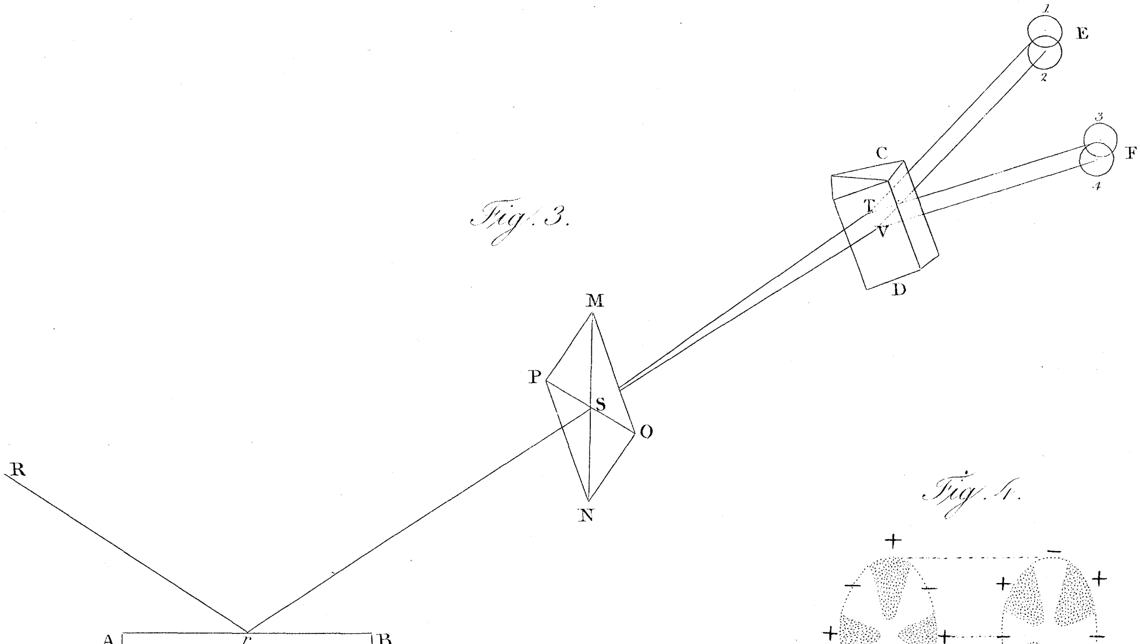
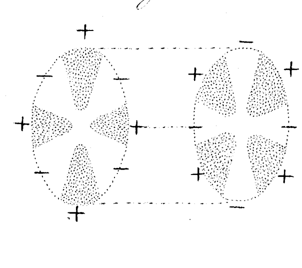


Fig. 4.



and deflexion, yet we are not entitled to employ this conjecture in the explanation of phenomena.

7. In all the preceding cases of depolarisation, the depolarised image continues visible in every part of the circular motion of the prism of calcareous spar, but there are cases where the vanished image is restored, and again vanishes during the revolution of the prism.

This phenomenon takes place when the polarised pencil is depolarised by transmitting it along the short diagonal of a rhomb of calcareous spar, or along the axis of a hexaedral prism of nitre, or through a parcel of glass plates, or through plates of agate and carbonate of barytes, that give a bright and a nebulous image. In all these cases only one bright image is produced, so that the images must vanish alternately in every quarter of a revolution, the only effect of the depolarising body being to polarise the light in a different plane, and thus to shift the vanishing place of the images.

Hence it follows that every body which possesses this kind of depolarisation, forms either a bright and a nebulous image, like the agate, or a single image, the light of which is all polarised in the same manner.

I have the honour to be, &c.

DAVID BREWSTER.

Edinburgh, October 22, 1814.